Lighting unit

The invention relates to a lighting unit having a discharge lamp, in particular a high pressure or high intensity discharge (HID) lamp or an ultra high performance (UHP) lamp, a lamp driver and a cooling device. The invention also relates to a projection system having such a lighting unit.

Because of their optical properties, high intensity discharge lamps and in particular UHP lamps are used inter alia preferably for projection purposes with displays or in projection systems. It has been demonstrated that the service life of discharge lamps is determined substantially by the operating parameters, such as in particular the lamp current, the lamp power and the temperature and temperature differences in the lamp and in particular in the wall of the discharge vessel.

Of particular significance is the thermal loading of the lamp, which may vary considerably depending on its installation situation, surrounding environment and size. In order to reduce the associated risk of a reduction in service life, in the case of lamps of relatively low power excessive heating is prevented by a suitable lamp design, in particular appropriate lamp geometry. In the case of higher power lamps, an active cooling device is generally necessary.

An appropriate lamp geometry and an active cooling device for an electrodeless discharge lamp (EHID) are known, for example, from US-PS 6,016,031. The cooling device comprises an air pressure source and one or more nozzles, with which an air stream is directed onto the top of the lamp or evenly onto all sides. The air pressure is rated and the shapes and dimensions of the cross-sections of the nozzles are selected in such a way that the surface temperature of the lamp does not exceed a given value, which would lead to a reduction in service life.

Account must be taken, on the one hand, of the fact that, during operation of the lamp, certain areas heat up particularly strongly and have to be cooled correspondingly strongly. On the other hand, however, the areas with the lowest temperature must not be excessively cooled, since a sufficiently high mercury vapor pressure can otherwise no longer arise in the discharge chamber. Moreover, there is a risk of the temperature differences in the

wall of the discharge vessel becoming excessive and of high mechanical stresses building up, which may in turn lead to a reduction in the service life or even to destruction of the lamp.

It has also emerged that the temporal and spatial temperature gradients become greater, the higher the operating temperature or power of the lamp and the more strongly or more differently individual wall areas are cooled with an active cooling device.

This problem is particularly serious during the switching on and off phases of the lamp, since the temperature conditions in these phases change very quickly and to a considerable extent.

If, for example, the lamp is switched off, the heat-generating plasma breaks down and thus also the thermal convection current in the discharge vessel. The consequences of this are that the temperature distribution in the wall of the discharge vessel changes and the wall areas cool off to differing extents and at different rates in accordance with their varying temperatures in the operating state. In this way, considerable mechanical stresses may arise in the wall of the discharge vessel, which may lead to immediate destruction of the lamp or at least to a reduction in the service life of the lamp. This problem may also occur in like manner when the lamp is switched on.

It is therefore an object of the invention to provide a lighting unit of the above-mentioned type with which a longer service life may be achieved in particular when using high-power lamps or the lamp may be operated with increased power while maintaining the same length of service life.

A further object of the invention is to provide a lighting unit of the above-mentioned type, which eliminates at least to a considerable extent the effect associated with switching the lamp on and off of reducing the service life or destroying the lamp.

In particular, it is intended to provide a lighting unit of the above-mentioned type in which the lamp may be so operated that the mechanical stresses in the light bulb and in particular in the discharge vessel caused by temperature fluctuations are substantially less during all operating phases or at least do not reach a level at which they reduce the service life in comparison to known lighting units.

Finally, it is intended to provide a lamp driver in particular for use in a lighting unit of the above-mentioned type or in a projection system having such a lighting unit, with which lamp driver a discharge lamp and/or a cooling device may be operated in such a way, especially during switching on/off, that the service life of the lamp is extended in comparison to known lamp drivers or the lamp may be operated with increased power for the same service life.

The object as claimed in claim 1 is achieved with a lighting unit having a discharge lamp, a lamp driver, a cooling device, at least one device for detecting at least one predetermined operating parameter of the discharge lamp, together with a control unit for controlling the lamp driver and/or the cooling device at least during switching on and/or off of the lighting unit in such a way that there is no excursion from a predetermined range of the at least one operating parameter.

Operating parameters should be understood, in this context, to mean not only the lamp power or the lamp current, but also the temperature of the lamp and in particular the temperatures in the wall of the discharge vessel of the lamp. In addition, it has emerged that these temperatures are largely dependent on the power of an active cooling device acting on the lamp and in particular on an air or gas stream directed onto the lamp, such that, on the basis of this direct influence, the cooling power of the cooling device should also be one of the operating parameters of the lamp.

The type and range of one or more of these operating parameters, from which range there should be no excursion at least during switching on and/or off, are selected as a function of the detectability thereof and of the type of lamp used as well as with regard to whether primarily the service life of the lamp is to be extended or the lamp is to be operated with the same service life at increased power.

The object is further achieved with a control unit as claimed in claim 9, a lamp driver as claimed in claim 10 and a projection system as claimed in claim 11.

A substantial advantage of these solutions is that high mechanical stresses in the wall of the discharge vessel, which have a service life-reducing effect, may be prevented therewith during switching on and off of the lamp.

At this point it should be mentioned that it is known from DE 17 64 728 to cool a gas discharge lamp with a fan which is operated with a switching device in such a way that it is activated with a time delay after switching on of the lamp at a first, low cooling power and continues at a second, high cooling power for a given time period after the lamp has been switched off. In this way, the lamp is intended on the one hand to achieve its operating temperature as quickly as possible after switching on and on the other hand to cool down as quickly as possible after switching off, so that it may optionally be switched back on again after only a short period.

However, it has become clear that this does not allow the lamp to cool rapidly in an even enough manner to prevent considerable mechanical stresses from arising in the discharge vessel and the risk thereby arises, in particular with high intensity lamps, of a

reduction in the service life of the lamp or even destruction thereof. Because of this discovery, this publication is not deemed relevant with regard to solving the problem forming the basis of the invention.

The dependent claims contain advantageous further developments of the invention.

Claims 2 and 3 contain operating parameters of the lamp which are preferably to be detected, while claim 4 covers rating of a range for an operating parameter.

Claim 6 describes a type of control which is particularly preferred in routine lamp operation, with which excursions from the predetermined range of an operating parameter of the lamp, in particular the temperature thereof, are prevented.

Claims 7 and 8 relate to preferred methods of control during switching on and off the lamp.

Finally, claim 10 describes a lamp driver, to which a discharge lamp and a cooling device may be connected for control in the above-described manner and which is particularly suitable for control during switching on/off.

The invention will be further described with reference to examples of embodiments shown in the drawings to which, however, the invention is not restricted. In the Figures:

Fig. 1 is a schematic overall representation of a lighting unit according to the invention; and

Fig. 2 is a schematic block diagram of a lamp driver with a control unit.

According to Fig. 1, the lighting unit comprises a discharge lamp 1 with a discharge vessel 11, in which there are located a discharge chamber with a discharge gas and two electrodes, between whose tips an arc discharge is induced when the lamp is in the operating state. On opposing sides, the discharge vessel 11 in each case comprises a metal-quartz bushing 12, 13 with in each case one metallic conductor connected to the electrodes as well as an electrical terminal via which the lamp voltage is supplied in known manner.

To this end, the electrical terminals of the discharge lamp 1 are connected to the electrical output terminals of a lamp driver 2. The input voltage generally takes the form of a line voltage (not illustrated) applied to the lamp driver 2. The lamp driver 2 thus serves

to transform the line voltage into a lamp voltage suitable for operating the discharge lamp and makes available the current necessary therefor, when the lamp is switched on, for example by means of a switch (not shown) on the lamp driver 2.

As has already been explained, discharge lamps, in particular high power discharge lamps, have to be actively cooled during operation. This task is performed by a cooling device 3, which generally contains a gas, in particular an air, pressure source and which directs a gas or air stream onto the lamp 1, in particular the discharge vessel 11, via a pressure line 31 with a nozzle 32.

To detect the power of the cooling device 3, in particular the velocity of the gas stream leaving the nozzle 32, a first sensor 33 is provided which is connected to the lamp driver 2 for evaluation of the sensor signal. As an alternative or in addition thereto, a further sensor may also be arranged in the pressure line 31, with which sensor, for example, the volume or pressure of the gas stream conveyed to the lamp 1 is detected and transmitted to the lamp driver 2. Evaluation of one of these variables allows not only monitoring of the cooling device 3, for example with regard to a fault or a failure, but also specific control of the cooling power acting on the lamp 1, in order in this way to influence the temperature thereof and to keep it within a predetermined range.

As an alternative and/or in addition thereto, this first sensor 33, by evaluating the sensor signal, may also allow a conclusion to be drawn with regard to the lamp temperature, since this is dependent on the cooling power acting thereon, for example in the form of the volume of the cooling air stream directed onto the lamp per unit time.

To control the cooling power, for example, the speed of rotation of a drive of a pressure pump in the cooling device 3 is varied appropriately or a shut-off valve in the pressure line 31 is opened or closed.

A second sensor 34 may be arranged on the discharge vessel 11 of the lamp 1, which sensor 34 detects the lamp temperature and in particular the temperature in the wall of the discharge vessel 11. This second sensor 34 is also connected to the lamp driver 2 for evaluation of the sensor signal. However, such a second sensor 34 directly on the lamp 1 is not generally necessary since, as explained above, the temperature thereof may be determined or detected sufficiently precisely by means of the power of the cooling device. To this extent, use of the second sensor 34 is generally only necessary as an alternative to the first sensor 33.

However, a further, essential operating parameter of the lamp 1 in the form of the lamp current and/or the lamp voltage and/or the lamp power is detected by means of an appropriate device in the lamp driver 2.

An electrical connection is provided between the cooling device 3 and the lamp driver 2 for activation of the former by the latter.

Finally, an on/off switch is generally located on the lamp driver 2, through actuation of which switch the lamp 1 may be switched on and off.

A schematic block diagram of the lamp driver 2 is shown in Fig. 2. The lamp driver 2 substantially comprises a first unit 21, with which input terminals 20 are connected for supplying an alternating line voltage. The first unit 21 comprises, for example, a rectifier with downstream down converter and serves to generate a controlled direct voltage from the alternating line voltage.

The output of the first unit 21 is connected to a second unit 22, which comprises a commutator (for example in the form of a full bridge circuit) and with which the current waveform necessary for lamp operation is generated from the direct voltage supplied. The output of the second unit 22 is connected to the lamp 1. The first and second units 21, 22 together thus form a trigger circuit for the lamp 1.

The lamp driver 2 further comprises a control unit 23, to the first input of which the output signal of the first sensor 33 is applied. The control unit 23 comprises a second input, which is connected to the trigger circuit 21, 22 and via which the control unit 23 detects the lamp current and/or the lamp voltage and/or the lamp power. A first output of the control unit 23 is connected to the trigger circuit 21, 22, a second output of the control unit 23 is applied to the cooling device 3 for activation thereof.

The control unit 23 preferably takes the form of a microprocessor unit. As a function of the information supplied via the two inputs about the operating parameters of the lamp 1 (power of the cooling device 3 and lamp current and/or lamp voltage and/or lamp power) and as a function of the switch position of the on/off switch for the lamp 1, the output power of the lamp 1 (or the lamp current) and/or the power of the cooling device 3 may be controlled in accordance with various control or switching schedules.

On the one hand, it is thereby ensured that the lamp 1 is always cooled sufficiently during routine operation, for example by controlling the cooling power of the cooling device 3 as a function of the lamp temperature detected indirectly with the first sensor 33 or directly with the second sensor 34.

If, in the case of unfavorable operating and/or environmental conditions, the cooling power is insufficient (or the cooling device 3 operates defectively or fails) and thus the temperature of the lamp 1 exceeds a given maximum permissible, preset value, the lamp

current may be automatically reduced or switched off by means of the lamp driver 2 to prevent damage or destruction.

On the other hand, it is possible, even during switching on and/or off, for the lamp 1 and/or the cooling device 3 to be switched on or off and operated automatically, for example stepwise, in coordinated manner in such a way that the above-described mechanical stresses in the lamp 1 and in particular in the discharge vessel 11 are substantially less or do not exceed a predeterminable value.

To this end, the following operating parameters of the lamp 1 should be evaluated cyclically by the control unit 23 of the lamp driver 2:

The instantaneous temperature of the lamp 1 or the wall of the discharge vessel 11 is detected by evaluating the output signal of the second sensor 34.

As an alternative or in addition thereto, the cooling power to which the lamp 1 is exposed by the cooling device 2, and thus, as explained above, indirectly (also) the temperature of the lamp 1, may be detected by means of the first sensor 33 and/or the pressure sensor present in the pressure line 31.

Furthermore, the lamp current and/or the lamp voltage and/or the lamp power are scanned by appropriate sensor means in the control unit 23.

Various switching schedules may be produced with these variables during switching on and off:

In the simplest case, with a first switching schedule both the lamp 1 and the cooling device 3 are switched on and/or off directly by actuation of the on/off switch. This may be sensible if, for example, the lamp 1 is so dimensioned that the mechanical stresses arising are low and no damage to the lamp is to be feared, or if it is important that the cooling device 3 does not make any noise after the lamp 1 has been switched off.

With a second switching schedule, the lamp 1 is again switched off directly by actuation of the off switch, but the cooling device 3 remains active for a predetermined period of time. In this way, the lamp 1 is cooled down particularly quickly and may be switched on again after only a relatively short interval.

With a third switching schedule, the cooling device 3 is switched off directly by actuation of the off switch, while the lamp 1 remains active for a predetermined period of time. This ensures that mechanical stresses which have built up in the lamp 1 and in particular in the wall of the discharge vessel 11 during operating phases at reduced operating temperature are reduced by annealing at elevated temperature.

In a fourth switching schedule, the lamp 1 and the cooling device 3 are reduced in power alternately and/or stepwise when the off switch is actuated. This may be achieved, for example, in that the power of the cooling device 3 is adjusted as a function of the current supplied instantaneously to the lamp 1 (or the lamp power) and/or the lamp current (or the lamp power) is adjusted as a function of the instantaneous power of the cooling device 3.

Furthermore, the lamp power and the power of the cooling device 3 are also reduced stepwise in such a way that the lamp 1 is operated ultimately at reduced power without the cooling device 3, in order thereby to eliminate mechanical stresses in the lamp in accordance with the third switching schedule by annealing at elevated temperature.

In a fifth switching schedule, actuation of the off switch effects immediate switching off of the lamp 1 and an increase in cooling power for a predetermined period of time after switching off of the lamp 1. The particularly rapid cooling effected thereby makes it possible to switch the lamp back on after a short period, as with the second switching schedule. Furthermore, with this switching schedule, mechanical stresses in the lamp 1 or in the wall of the discharge vessel 11 may be generated in a controlled manner, for example in order thereby to counter or compensate for mechanical stresses arising due to the uneven heating when the lamp is switched on. In such a case, overall only substantially lower mechanical stresses arise when the lamp is next switched on.

Comparative tests using the above-mentioned switching schedules have demonstrated that very different mechanical stress distributions may thereby be produced in the wall of the discharge vessel 11.

If, conversely, a given mechanical stress distribution is to be achieved or not exceeded, the numerical values of the above-mentioned switching schedules should be selected as a function of the operating parameters of the lamp 1 used and the power of the cooling device 3 together, for example, with the required explosion protection and service life of the lamp 1, the time available for switching on and off and the noise level tolerable with regard to use of the lighting unit.

Examples of the numerical values for the fourth switching schedule are given below. It should be assumed that the discharge lamp is cooled during operation with an air stream of approx. 2.9 liters per minute (l/min) and operated at a power of 450 watts.

If the moment at which a user moves the switch on the lamp driver 2 into the off position is designated time 0, the lamp power and the power of the cooling device are reduced as follows at this time and after the subsequent intervals (Table 1):

Table 1:

0 sec.	400 watts	2.5 l/min
30 sec.		2.2 l/min
60 sec.	360 watts	
90 sec.		1.9 l/min
120 sec.	320 watts	
150 sec.		1.7 l/min
180 sec.	280 watts	
210 sec.		1.5 l/min
240 sec.	240 watts	
270 sec.		1.3 l/min
300 sec.	0 watts	0 l/min

This Table is preferably stored in the control unit 23, in particular the microprocessor unit, present in the lamp driver 2, such that the control unit 23 regulates the power of the lamp 1 and the cooling device 3 in the manner described.

It is clear from the Table that every 30 seconds from actuation of the switch the lamp power or the power of the cooling device 3 is reduced, while the respective other variable remains unaltered. It has been demonstrated that the lamp temperature and in particular the temperature of the discharge vessel 11 may thereby be reduced in a highly controlled manner and without great fluctuations over the entire switching-off phase.

It has also been demonstrated that, after the end of the switching-off phase, i.e. after five minutes, while the maximum temperature of the lamp 1 has only been reduced slightly, the level of the temperature gradients in the wall of the discharge vessel 11 has reduced considerably. This has the direct result that the mechanical stresses are accordingly also slight. Further tests have shown that this effect is achieved to a particularly great extent at high lamp powers.